California High-Speed Train Project


# TECHNICAL MEMORANDUM

## Engineering Survey and Mapping
## TM 1.1.4

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Prepared by 


for the California High-Speed Rail Authority

# System Level Technical and Integration Reviews

The purpose of the review is to ensure:

- Technical consistency and appropriateness
- Check for integration issues and conflicts

System level reviews are required for all technical memoranda. Technical Leads for each subsystem are responsible for completing the reviews in a timely manner and identifying appropriate senior staff to perform the review. Exemption to the system level technical and integration review by any subsystem must be approved by the Engineering Manager.

System Level Technical Reviews by Subsystem:

| | | |
|---|---|---|
| Systems: | NOT REQUIRED<br>Print Name: | <br>Date |
| Infrastructure: | NOT REQUIRED<br>Print Name: | <br>Date |
| Operations: | NOT REQUIRED<br>Print Name: | <br>Date |
| Maintenance: | NOT REQUIRED<br>Print Name: | <br>Date |
| Rolling Stock: | NOT REQUIRED<br>Print Name: | <br>Date |

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# ABSTRACT

The California High-Speed Train Project (CHSTP) is proposed to provide a high-speed intercity rail service state-wide and will demand accurate and consistent geospatial information along the entire high-speed rail network.

This technical memorandum outlines the requirements for horizontal and vertical datum and control, photogrammetric mapping accuracy, depiction of man-made features and existing property information, digital terrain modelling (DTM), and engineering survey procedures aimed to support design development through the 30% Design level. This technical memorandum includes review of current standards and polices already in place governing compilation of aerial mapping and land surveying procedures with an objective to establish guidance applicable to the CHSTP.

The approach presented in this technical memorandum for assessing applicable mapping and survey requirements is generally based on National Geodetic Survey (NGS), United States Geologic Survey (USGS) standards, and current Caltrans policies and practices developed by the Caltrans Office of Land Surveys. Where appropriate, project-specific guidance is provided to supplement or clarify mapping and survey needs of the CHSTP.

This technical memorandum does not address requirements for right-of-way and construction surveys or include procedures for preparation of survey plats, legal descriptions, or construction staking notes. These topics will be addressed in separate technical memoranda during subsequent design phases of the program.

# 1.0 INTRODUCTION

The California High-Speed Train Project (CHSTP) is proposed to provide a high-speed intercity rail service state-wide and will demand accurate and consistent geospatial information along the entire high-speed rail network. This technical memorandum reviews current standards and polices already in place governing compilation of aerial mapping and land surveying procedures with an objective to establish guidance applicable to the CHSTP.

## 1.1 PURPOSE OF TECHNICAL MEMORANDUM

This technical memorandum establishes the requirements and expectations for the compilation of topographic mapping and performing engineering land surveys required for advancing design of the CHSTP through the 30% Design level. Particular emphasis is placed on the accurate reflection of existing topographic and man-made features in the mapping requirements, and the establishment of adequate terrain models used for the design and development of earthwork quantities.

This technical memorandum does not address requirements for right-of-way and construction surveys or include procedures for preparation of survey plats, legal descriptions, or construction staking notes. These topics will be addressed in separate technical memoranda during subsequent design phases of the program.

## 1.2 STATEMENT OF TECHNICAL ISSUE

The CHSTP will require engineering, survey and topographic mapping data to determine existing ground conditions and facilities located within the project corridor, establishing horizontal and vertical rail alignments, developing digital terrain models for use in design, and generating accurate earthwork cross-sections for cost estimating purposes.

## 1.3 GENERAL INFORMATION

In general, the topic of this technical memorandum is well covered in several national and state issued procedures and guidelines. The mapping and surveying discussed below will follow applicable recommended practices defined by National Geodetic Survey (NGS) and United States Geologic Survey (USGS) standards, the U.S. Bureau of Land Management's Manual of Surveying Instructions (1973), Caltrans Surveys Manual (2006), the Caltrans User's Guide to Photogrammetric Products and Services (1996), and the Manual of Photogrammetry, 5th Edition by the American Society of Photogrammetry and Remote Sensing (2004).

### 1.3.1 Definition of Terms

The following technical terms and acronyms used in this document have specific connotations with regard to California High-Speed Train system.

California Coordinate System of 1983 (CCS 83): The system of plane coordinates which has been established by the National Geodetic Survey for defining or stating the positions or locations of points on the surface of the earth within the State of California and which is based on the North American Datum of 1983.

Contours: A variable curve that connects points with the same elevation value used to depict surface elevations on a contour map.

Control: An established point on the earth's surface with a known coordinate in the X, Y, Z and used for reference and mapping of field surveys.

Controlled Access: Full or partial restriction of the access of owners or occupants of abutting land to or from a highway and/or railway.

Datum: A reference from which measurements are made for establishing horizontal and vertical control.

Digital Terrain Model: A three-dimensional model of digital surfaces of topographic features.

EPOCH: A specific date (time stamp) that all positions are based upon.

GEOID09: Gravimetric hybrid geoid height model developed by NGS containing the separation between NAD83 and NAVD88 and is the basis for elevations (orthometric heights) using GPS survey methods.

National Spatial Reference System (NSRS): Datum, defined and managed by the National Geodetic Survey, and the foundation for the National Spatial Data Infrastructure (NSDI).

North American Datum of 1983 (NAD 83): The horizontal control datum for the United States based on the Geodetic Reference System 1980 and with a geocentric origin.

North American Vertical Datum of 1988 (NAVD 88): The vertical control datum established for surveying elevations in the United States based on the General Adjustment of the North American Datum of 1988.

Parcel: A distinct, continuous portion or tract of land.

Photogrammetry: The art, science, and technology of obtaining reliable information about physical objects and the environment through process of recording, measuring, and interpreting images and patterns of electromagnetic radiant energy and other phenomena.

Plat: A plan or map of a plot of ground.

Ownership: Any interest in land, real estate, or the improvements on it.

Right-of-way: A general term for a strip of land, or rights in a strip of land, used for highway, railway, public utility services, or other purposes. The right-of-way line of a freeway or railway is usually the access control line.

Scale: A graduated line representing a proportionate size.

Topographic Map: A map of the features of the actual surface of the earth considered collectively as to form.

Acronyms

| | |
|---|---|
| APN | Assessors Parcel Number |
| ASPRS | American Society for Photogrammetry and Remote Sensing |
| Authority | California High-Speed Rail Authority |
| CADD | Computer Aided Design and Drafting |
| Caltrans | California Department of Transportation |
| CCS | California Coordinate System |
| CFR | Code of Federal Regulations |
| CHSTP | California High-Speed Train Project |
| DARC | District Airspace Review Committee |
| DEIR/S | Draft Environmental Impact Report / Statement |
| DTM | Digital Terrain Model |
| FRA | Federal Railroad Administration |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| NAD | North American Datum |
| NAVD | North American Vertical Datum |
| NGS | National Geodetic Survey |
| PMT | Program Management Team |
| TSSS | Total Station Survey System |
| TIN | Triangulated Irregular Network |
| USGS | United States Geological Survey |

### 1.3.2 Units

The California High-Speed Train Project is based on U.S. Customary Units consistent with guidelines prepared by the California Department of Transportation and defined by the National Institute of Standards and Technology (NIST). U.S. Customary Units are officially used in the United States, and are known as “English” or “Imperial” units. In order to avoid confusion, all formal references to units of measure should be made in terms of U.S. Customary Units. All surveys and mapping for the CHSTP shall be based on the linear unit known as “US Survey Feet”.

# 2.0 DEFINITION OF TECHNICAL TOPIC

## 2.1 GENERAL

The CHSTP is proposed as an intercity rail network expanding across the entire state, and will require a common set of standards and procedures governing the development of mapping products and the performance of field surveys in support of design activities advancing the project. The CHSTP requires a systematic approach in dealing with land surveying and mapping development. This technical memorandum is focused on establishing appropriate standards relevant to the compilation of mapping and the performance of field surveys.

### 2.1.1 CHSTP Design Considerations

Consistent, accurate, and detailed mapping and survey information will serve as a foundation for all aspects of the design. In the effort to meet this objective, the CHSTP will adopt appropriate mapping and engineering survey standards and procedures.

### 2.1.2 CHSTP Design Parameters

The CHSTP has adopted certain standards and requirements for aerial mapping and land surveying. The Caltrans Surveys Manual serves as the basis for surveying and mapping for the CHSTP.

# 3.0 ASSESSMENT / ANALYSIS

In order to effectively support the design activities along the CHSTP route, the mapping and engineering surveying shall accurately depict existing topography, man-made features, and any other pertinent information that may potentially impact the design process and project costs.

## 3.1 GENERAL

This section provides general guidance on the requirements specific to the mapping and surveying elements to be prepared for the CHSTP.

## 3.2 ASSESSMENT

### 3.2.1 Analysis

The activities and products associated with mapping and field surveying for the CHSTP, in general, are not unique to the CHSTP. However, strict compliance with horizontal and vertical controls, accuracy standards, surveying procedures, and mapping compilation practices being mandated by national standards and applicable Caltrans manuals will ensure the CHSTP's consistency as a state-wide system and its compatibility with mapping and surveying materials developed for other infrastructure elements throughout the State of California.

### 3.2.2 CHSTP Standards for Engineering Survey and Mapping

In general, surveys for the CHSTP shall be based the Caltrans Survey Manual. Section 6.1 - Design Manual Criteria, which presents specific citations and exceptions.

### 3.2.3 Applicability

Where applicable, the general basis for mapping and surveying standards will be the most appropriate of the recommended practices described in the following documents:

- State of California Land Surveyors Act, California Business & Professions Code 8700-8805 (2010)
    - www.pels.ca.gov/licensees/pls_act.pdf
- Caltrans Surveys Manual (2006)
    - www.dot.ca.gov/hq/row/landsurveys/SurveysManual/Manual_TOC.html
- Caltrans User's Guide to Photogrammetric Products and Services (1996)
    - www.dot.ca.gov/hq/esc/photogrammetry/resources/UsersGuide1996.pdf
- U.S. Bureau of Land Management's Manual of Surveying Instructions (1973)
    - www.blm.gov/cadastral/Manual/73man/id1.htm
- USGS National Map Accuracy Standards
    - http://erg.usgs.gov/isb/pubs/factsheets/fs17199.html
- Manual of Photogrammetry, 5th Edition by the American Society of Photogrammetry and Remote Sensing (2004)
    - www.asprs.org
- Caltrans Plans Preparation Manual
    - http://www.dot.ca.gov/hq/oppd/cadd/usta/ppman/default.htm

In the case of differing values, conflicts in the various requirements for design, or conflicts between source information, the standard followed shall be that which results in the highest level of satisfaction for all requirements or that which is deemed as the most appropriate. The standard shall be followed as required for securing regulatory approval.

### 3.2.4 Regulatory Requirements

All mapping will be prepared to the appropriate scale as required by its intended use; all project surveys and mapping shall be based on State Plane Coordinates. All surveys and mapping activities will be performed under the direct supervision of a Professional Land Surveyor (PLS), licensed in the State of California, in accordance with the Professional Land Surveyor's Act.

## 3.3 DESIGN SURVEY AND MAPPING

### 3.3.1 Horizontal and Vertical Datum

The survey datum used for the CHSTP shall be based on the following:

1. The California Coordinate System of 1983 (CCS 83) is the coordinate system used for all mapping, planning, design, right-of-way engineering, and construction.
2. The North American Datum of 1983, NAD 83 (NSRS) as defined by the National Geodetic Survey shall be used for horizontal datum for all mapping, planning, design, right-of-way engineering, and construction. The epoch for all positions will be 2007.00, and is referred to as NAD 83 (2007), which is equivalent to NAD 83 (NSRS2007)
3. The North American Vertical Datum of 1988 (NAVD 88) as defined by the National Geodetic Survey (NGS) shall be used for all mapping, planning, design, right-of-way engineering, and construction. Surveys based on GPS methods shall use the model GEOID09 for all processing. The data for GEOID09 from NGS can be obtained using the following web link:

   http://www.ngs.noaa.gov/GEOID/GEOID09/

   Reference is made to California Coordinate System, California Public Resources Code Section 8801-8819

   Reference is made to Official Geodetic Datums Spatial Reference Network, California Public Resources Code Section 8850-8861

   Reference is made to California Geodetic Coordinates of 1983, California Public Resources Code Section 8870-8880

   Reference is made to California Orthometric heights of 1988, California Public resources Code Section 8890-8902

### 3.3.2 Accuracy and Standards

Surveys performed for the CHSTP shall be developed with the accuracy and standards and field procedures as defined in the Caltrans Surveys Manual, 2006 or current edition. Surveys shall conform to the specifications of accuracy per Caltrans Figure 5-1A titled "CALTRANS ORDERS of SURVEY ACCURACY". Applicable chapters of the Caltrans Surveys Manual (2006) include:

- Chapter 5 – "Classifications of Accuracy and Standards"
- Chapter 6 – "Global Positioning System (GPS) Survey Specifications"
- Chapter 7 – "Total Station Survey System (TSSS) Survey Specifications"
- Chapter 8 – "Differential Leveling Survey Specifications"
- Chapter 9 – "Control Surveys"
- Chapter 10 – "Right of Way Surveys"
- Chapter 11 – "Engineering Surveys"
- Chapter 12 – "Construction Surveys"

The following is a link to Caltrans Figure 5-1A

http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/Fig_5_1A_Ratio-2006.pdf

Conversion of units from US Survey Foot to international meter may be necessary in order to apply standards listed above. This conversion is defined as follows:

- 1 US Survey Foot = 1200/3937 meters – see CA Public Resources Code Sec 8810

### 3.3.3 Errors and Adjustments

Errors and adjustments to field surveys shall be in accordance with Chapter 5 of the Caltrans Survey Manual.

### 3.3.4 Control Surveys

A network of control survey monuments will be established at two mile intervals along the CHSTP alignment. These control monuments will be used in all future surveys to ensure that all survey activities are based on the same adjustment positions and epoch, so that transitions between zones of the California Coordinate System are handled uniformly and correctly. The network will be established during preliminary design and maintained through the construction period by PMT oversight. Horizontal datum will be NAD 83 and the epoch will be (2007), commonly known as NAD 83(2007), which is equivalent to NAD 83(NSRS2007).

Vertical datum will be NAVD 88. All surveys using GPS methods and equipment shall use the NGS model GEOID09 for all processing.

All mapping will be based of the California Coordinate System (CCS 83) in US Customary Units. The control survey monuments will be used for all phases of the Project: 30%, Final Design, right-of-way definition and delineation, and construction control.

### 3.3.5 Photogrammetric and Topographic Mapping Surveys

Different levels of mapping accuracy are appropriate for preliminary and advanced design. Two levels of topographic mapping are proposed for use on the project

Photogrammetric mapping at 1" = 100' scale controlled using Airborne GPS methods and generating digital terrain model (DTM) mapping with 2' contour intervals is adequate for preliminary (30%) design. This mapping can be used to develop pre-final alignments, identify whole property impacts, and to determine preliminary earthwork and other quantities for cost estimating. This level of mapping does not have sufficient accuracy for detailed design or construction and is inadequate to define partial property takes. This mapping can be developed faster and is less expensive to prepare than fully-controlled design scale photogrammetry.

Fully-controlled photogrammetry generating 1" = 50' mapping with 1' contours to National Mapping Accuracy standards is appropriate for detailed design and construction. The accuracy of this mapping is required to finalize alignments and design, and also to confirm property impacts. Development of this mapping is more expensive and requires longer time to prepare than Airborne GPS.

Color digital ortho imagery will be provided as a by-product to the photogrammetry deliverable. Establishment of survey control and quality review is required for all photogrammetry and mapping services. Field verification by ground level surveying is required as part of the mapping effort in order to establish that the product has met the specified accuracy standards. A report is to be provided by the mapping team and independently checked by the design teams.

All topographic mapping will adhere to US National Map Accuracy Standards. Topographic mapping requirements for preliminary and final design are summarized in Table 3-1.

**Table 3-1: Topographic Mapping; Preliminary and Final Design**

| | Map Scale / Contour Interval | Max Width of mapping coverage | Flying Height / Photo Scale | Expected Resolution | Control | Comment |
|---|---|---|---|---|---|---|
| Preliminary design, to 30% | 1"=100" / 2' | 3780' | 3600'± AMT / 1:7200, 1"=600' | 0.35', pixel | Airborne GPS may be appropriate, with field verification | Detailed planimetrics not obtainable (water valves, manholes, fences, etc.) |
| Final design, post 30% | 1"=50' / 1' | 1890' | 1800'± AMT / 1:3600, 1"=300 | 0.20' pixel | Fully-controlled with multiple ground targets and field verification. AGPS not appropriate | This mapping will meet Caltrans technical standards for design scale mapping |

### 3.3.6 Digital Terrain Model

Topographic aerial mapping supplemented as necessary by the field surveys is used to develop a Digital Terrain Model (DTM) that mathematically defines the existing ground surface conditions. The CHSTP will utilize DTM surfaces as a basis for defining vertical alignments, preparation of cross-sections, and the generation of earthwork quantities.

The Digital Terrain Model shall be checked for accuracy and adjusted in accordance with Caltrans Photogrammetry requirements. The DTM shall be prepared in accordance with the CHSTP CADD Standards and provided in a format compatible with the CHSTP design software requirements.

### 3.3.7 Design Survey and Mapping Deliverables

All drawings, plans, specifications, photographs, aerial photography, topographic mapping, digital terrain models, color digital ortho imaginary, schematics, maps, reports, studies, analyses, estimates, minutes, diaries, survey data, field notes, calculations, summaries and other compilations of information to be developed, produced, or provided for the CHSTP, including but not limited to all identified deliverables, whether completed or in process, and all supporting documents and data, whether in hard copy or electronic or digital format shall become the property of the California High-Speed Rail Authority and shall be furnished to the Authority promptly upon request.

# 4.0 SUMMARY AND RECOMMENDATIONS

It is recommended that engineering survey and topographic mapping standards and procedures implemented on CHSTP follow standards as listed in Section 6.1 of this technical memorandum.

# 5.0 SOURCE INFORMATION AND REFERENCES

The following reference materials were reviewed and considered in the development of this Technical Memorandum:


1. State of California Land Surveyors Act, California Business & Professions Code 8700-8805 (2010)
    - www.pels.ca.gov/licensees/pls_act.pdf
2. Caltrans Surveys Manual (2006)
    - www.dot.ca.gov/hq/row/landsurveys/SurveysManual/Manual_TOC.html
3. Caltrans User's Guide to Photogrammetric Products and Services (1996)
    - www.dot.ca.gov/hq/esc/photogrammetry/resources/UsersGuide1996.pdf
4. U.S. Bureau of Land Management's Manual of Surveying Instructions (1973)
    - www.blm.gov/cadastral/Manual/73man/id1.htm
5. USGS National Map Accuracy Standards
    - http://erg.usgs.gov/isb/pubs/factsheets/fs17199.html
6. Manual of Photogrammetry, 5th Edition by the American Society of Photogrammetry and Remote Sensing (2004)
    - www.asprs.org
7. Caltrans Plans Preparation Manual (2008)
    - http://www.dot.ca.gov/hq/oppd/cadd/usta/ppman/default.htm

# 6.0 DESIGN MANUAL CRITERIA

## 6.1 DESIGN SURVEY AND MAPPING

### 6.1.1 Horizontal and Vertical Datum

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3. The North American Vertical Datum of 1988 (NAVD 88) as defined by the National Geodetic Survey (NGS) shall be used for all mapping, planning, design, right-of-way engineering, and construction. Surveys based on GPS methods shall use the model GEOID09 for all processing. The data for GEOID09 from NGS can be obtained using the following web link:

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### 6.1.3 Errors and Adjustments

Errors and adjustments to field surveys shall be in accordance with Chapter 5 of the Caltrans Survey Manual.

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Vertical datum will be NAVD 88. All surveys using GPS methods and equipment shall use the NGS model GEOID09 for all processing.

All mapping will be based of the California Coordinate System (CCS 83) in US Customary Units. The control survey monuments will be used for all phases of the Project: 30%, Final Design, right-of-way definition and delineation, and construction control.

### 6.1.5 Photogrammetric and Topographic Mapping Surveys

Different levels of mapping accuracy are appropriate for preliminary and advanced design. Two levels of topographic mapping are proposed for use on the project

Photogrammetric mapping at 1" = 100' scale controlled using Airborne GPS methods and generating digital terrain model (DTM) mapping with 2' contour intervals is adequate for preliminary (30%) design. This mapping can be used to develop pre-final alignments, identify whole property impacts, and to determine preliminary earthwork and other quantities for cost estimating. This level of mapping does not have sufficient accuracy for detailed design or construction and is inadequate to define partial property takes. This mapping can be developed faster and is less expensive to prepare than fully-controlled design scale photogrammetry.

Fully-controlled photogrammetry generating 1" = 50' mapping with 1' contours to National Mapping Accuracy standards is appropriate for detailed design and construction. The accuracy of this mapping is required to finalize alignments and design, and also to confirm property impacts. Development of this mapping is more expensive and requires longer time to prepare than Airborne GPS.

Color digital ortho imagery will be provided as a by-product to the photogrammetry deliverable. Establishment of survey control and quality review is required for all photogrammetry and mapping services. Field verification by ground level surveying is required as part of the mapping effort in order to establish that the product has met the specified accuracy standards. A report is to be provided by the mapping team and independently checked by the design teams.

All topographic mapping will adhere to US National Map Accuracy Standards. Topographic mapping requirements for preliminary and final design are summarized in Table 6-1.

**Table 6-1: Topographic Mapping; Preliminary and Final Design**

| | Map Scale / Contour Interval | Max Width of mapping coverage | Flying Height / Photo Scale | Expected Resolution | Control | Comment |
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| Final design, post 30% | 1"=50' / 1' | 1890' | 1800'± AMT / 1:3600, 1"=300 | 0.20' pixel | Fully-controlled with multiple ground targets and field verification. AGPS not appropriate | This mapping will meet Caltrans technical standards for design scale mapping |

### 6.1.6 Digital Terrain Model

Topographic aerial mapping supplemented as necessary by the field surveys is used to develop a Digital Terrain Model (DTM) that mathematically defines the existing ground surface conditions. The CHSTP will utilize DTM surfaces as a basis for defining vertical alignments, preparation of cross-sections, and the generation of earthwork quantities.

The Digital Terrain Model shall be checked for accuracy and adjusted in accordance with Caltrans Photogrammetry requirements. The DTM shall be prepared in accordance with the CHSTP CADD Standards and provided in a format compatible with the CHSTP design software requirements.

### 6.1.7 Design Survey and Mapping Deliverables

All drawings, plans, specifications, photographs, aerial photography, topographic mapping, digital terrain models, color digital ortho imaginary, schematics, maps, reports, studies, analyses, estimates, minutes, diaries, survey data, field notes, calculations, summaries and other compilations of information to be developed, produced, or provided for the CHSTP, including but not limited to all identified deliverables, whether completed or in process, and all supporting documents and data, whether in hard copy or electronic or digital format shall become the property of the California High-Speed Rail Authority and shall be furnished to the Authority promptly upon request.